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PHYSICAL FITNESS AND PHYSICAL PERFORMANCE DURING CONTINUOUS FIELD ARTILLERY OPERATIONS

U S ARMY RESEARCH INSTITUTE
OF

ENVIRONMENTAL MEDICINE

Natick, Massachusetts

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post-scenario. Measures of muscular strength and lifting capacity, however, increased by 12-18% post-scenario. Physical performance scores were significantly higher on days 1 and 8 compared to the other days but no differences were seen from days 2 through 7. The mean \pm SD daily amount of sleep obtained was 5.3 \pm 1.3 hrs. The soldiers averaged 2.5 hr, 22 min. and 2.9 min per day at heart rates equal to or greater than 25%, 50%, and 75% of their maximal heart rates, respectively. The results suggest that

- 1) soldiers who are allowed 5 hrs sleep per day and who are required to perform at relatively moderate levels of physical intensity show no decrements in physical fitness capacity or evidence of physical fatigue for up to 8 days of continuous operations,
- 2) the physical fitness of artillerymen was comparable to other Army populations of similar age and proved adequate to meet the physical demands of this scenario, and
- 3) soldiers undergoing realistic, continuous field artillery operations are able to obtain adequate sleep and spend only short periods at high levels of physical activity.

DISCLAIMERS

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

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**Physical Fitness and Physical Performance
During Continuous Field Artillery Operations**

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FOREWARD

In April 1982 a conference on Applied Research in Physical Fitness was convened by the Army Physical Fitness Research Institute, US Army War College, to address priorities and research requirements in physical fitness and training. The number one priority identified by the conferees was the need to determine the physical demands placed upon the soldier during continuous combat operations. The first study conducted in this area was with the light infantry since it was assumed that the most physically demanding work in continuous operations would involve this combat arm. This study took place in July 1983 at Ft. Lewis, WA with soldiers from the 2nd Battalion, 47th Infantry Regiment, 3rd Brigade, 9th Infantry Division.

The study reported herein is the second in this series and deals with the physical demands encountered by the field artillery during continuous operations. The soldiers who participated in the study and those who provided the support were from the 2nd Battalion, 34th Field Artillery (III Corps), Ft. Sill, OK. The combat-realistic scenario was prepared by the Field Artillery Board, Ft. Sill, OK.

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ABSTRACT

The purposes of this study were to 1) determine the effects of a continuous field artillery scenario on physical fitness capacity and performance, 2) relate physical capacity to task performance during the scenario, and 3) estimate the physical intensity of the scenario by continuous heart rate monitoring. Twenty-four artillerymen comprising three, 8-man guncrews participated in an 8-day, combat-simulated operation. Body composition and measures of fitness (isokinetic strength of the arms and legs, isometric handgrip strength, dynamic lifting, and upper body anaerobic power) were determined before and immediately following the scenario. Physical performance was assessed by daily ratings from senior noncommissioned officers experienced in artillery operations. The intensity of physical activity and amount of sleep were estimated from continuously recorded heart rate using electrocardiographic tape recorders worn by the soldiers. Weak, non-significant relationships were found between various measures of exercise capacity and physical task performance during the scenario. No changes occurred in body weight or upper body anaerobic power from pre to post-scenario. Measures of muscular strength and lifting capacity, however, increased by 12-18% post-scenario. Physical performance scores were significantly higher on days 1 and 8 compared to the other days but no differences were seen from days 2 through 7. The mean (\pm SD) daily amount of sleep obtained was 5.3 ± 1.3 hrs. The soldiers averaged 2.5 hr, 22 min, and 2.9 min per day, respectively, at heart rates equal to or greater than 25%, 50%, and 75% of their maximal heart rates. The results suggest that 1) soldiers who are allowed 5 hrs sleep per day and who are required to perform at relatively moderate levels of physical intensity show no decrements in physical fitness capacity or evidence of physical fatigue for up to 8 days of continuous operations, 2) the physical fitness of artillerymen was comparable to other Army populations of similar age and proved adequate to meet the physical demands of this scenario, and 3) soldiers undergoing realistic, continuous field artillery operations are able to obtain adequate sleep and spend only short periods at high levels of physical activity.

INTRODUCTION

Continuous operations may be defined as those combat actions that are uninterrupted for a period of 24 hours or more. Such operations characterize the high-intensity, short-term war which has become the trend since the end of World War II. The 1967 and 1973 wars between Israel and Egypt and the 1982 Falklands war, for example, were over within a matter of days. During these short periods, the countries involved were engaged in very intense combat resulting in the loss of hundreds of lives. All such engagements have relied on the use of massive artillery barrages to inflict maximum damage on the target. In an article on the British experience in the Falklands, Bailey (1) stated that "in the last 12 hours of the battle for Port Stanley, five batteries fired the equivalent of one regiment's training ammunition allocation for four years." Based upon the recent past, future conflicts will undoubtedly be characterized by high intensity operations lasting for periods which may exceed an individual's capability to maintain efficient performance. It is apparent, therefore, that a high priority needs to be placed on assessing the physical demands and formulating physical fitness requirements for the combat soldier who must perform in such conditions.

Recently, efforts have been directed toward assessing the effects of continuous operations on human performance by employing prolonged, combat-simulated scenarios (2,3,4,5,6). Most such studies, however, have been concerned with the effects of sleep loss on vigilance tasks and cognitive performance (2,3,7) and have dealt only briefly with physical performance (2). The results of these studies have shown cognitive and vigilance tasks to rapidly deteriorate over time.

In military continuous operations, sleep loss is but one of many stresses facing the soldier. In studies involving both limited sleep and high levels of physical exertion decrements have been reported in various measures of muscular strength and anaerobic capacity (4,6). In a 5-day sustained combat infantry scenario in which subjects were given 4-5 hours sleep each 24 hours, Murphy et al. (4) found a decrease in upper body anaerobic power and isokinetic endurance. In an 8-day British field artillery loading trial, Legg and Patton (6) also found decrements in upper body anaerobic power as well as a progressive decrease in isometric handgrip strength throughout the trial.

The purpose of the present study, therefore, was to further investigate the impact of continuous operations on physical fitness capacity and physical task performance in field artillery soldiers operating for 8 days under combat simulated conditions. Specifically, the objectives of the study were to 1) relate individual levels of physical fitness to physical task performance during the scenario, 2) identify any decrements in physiological capacities as a result of the scenario, and 3) determine the physical intensity of the scenario by continuous monitoring of heart rate.

METHODS

Subjects were 24 qualified field artillery soldiers assigned to three M109A3, 155mm howitzer guncrews (8 men per gun). All subjects were fully briefed regarding the purpose and nature of the study and their informed consent was obtained prior to participation. These guncrews were the base gun from each of three field artillery batteries (3 howitzers and one fire direction control center per battery) designated as Alpha, Bravo, and Charlie who took part in a large field artillery exercise at Ft. Sill, OK from 28 May

to 5 June 1986. This was an 8-day continuous, combat-simulated scenario which involved frequent moves (5-7 per day), daily resupply missions, emplacement of camouflage twice daily, frequent fire missions (20 to 65 per day) requiring the handling and loading of shells weighing 45 kg, and other tasks normally associated with artillery operations. These activities were the same for all guncrews but varied in time of day according to individual guncrew scenario requirements. All subjects were provided the same amount of food and were able to maintain adequate and similar food and fluid intake throughout the exercise (8). The average temperature for the scenario was 20°C with a range of 14-29°C. The relative humidity averaged 79%.

The study design consisted of a baseline data collection phase followed by pre-scenario and post-scenario testing periods. During the baseline period, which took place approximately 10 days prior to the scenario, subjects were familiarized with the laboratory procedures and a complete physical fitness profile was performed. The tests comprised assessments of body composition, aerobic power, upper and lower body anaerobic power, muscular strength, and lifting capacity. The data from these tests were used to relate physical fitness capacities to subsequent physical performance assessed each day of the scenario.

Four days before the scenario during a 4 hr period in the morning and at approximately the same time of day immediately post-scenario, subjects also underwent a series of physiological tests to identify changes in physical fitness capacities pre to post-scenario. The tests were performed in the same order at both times and consisted of body composition, muscular strength measures, lifting capacity and upper body anaerobic power.

During the baseline phase, body composition was determined by hydrostatic weighing. Subjects entered a weighing tank clothed in a swimsuit with the water maintained at a constant temperature ($35-36^{\circ}\text{C}$). Subjects sat on an aluminum chair submerged and exhaled as much air as possible to their residual volume. A strain gauge recorded the subject's underwater weight while a stable reading was achieved (9). Residual lung volume was determined prior to entrance into the tank using the method of Wilmore et al. (10). In the pre and post-scenario tests, body composition was estimated from the sum of four skinfolds (biceps, triceps, sub-scapular and suprailiac) according to Durnin and Womersley (11).

Aerobic capacity was determined by measuring maximal oxygen uptake ($\dot{V}\text{O}_{2\text{max}}$) using a progressive, discontinuous protocol on a motor-driven treadmill (12). Subjects initially ran at 6 mph, 0% grade for 6 min after which the grade was increased to 5% and the speed held constant or increased to 6.5-7.0 mph. Each subsequent bout of exercise was performed for 3 minutes at grades increased by 2.5% until a plateau occurred in $\dot{V}\text{O}_2$. In the final minute at each intensity, expired air was collected in Douglas bags through a mouthpiece and low resistance (Koegel) breathing valve. Gas volumes were measured with a Tissot spirometer and O_2 and CO_2 fractions with fuel cell and infrared analyzers, respectively. Heart rate was monitored electrocardiographically throughout the test.

Anaerobic power was determined by the Wingate test (WT) (13) for both the upper body (arm cranking) and lower body (leg cycling) during the baseline phase. Only the upper body WT was repeated pre and post-scenario. The WT was performed on a cycle ergometer that had been modified with a lever arm for instantaneous application of resistance (14). The subject cycled or cranked

at maximal RPM's for 30s at resistance settings of 0.075 kg/kg body weight (BW) and 0.050 kg/kg BW, respectively. The number of pedal revolutions and the resistance were used to calculate power output in watts (W). Power outputs were expressed as peak power, the mean power of the highest 5s period; mean power, the average power output over the 30s; and power decrease, the difference between peak power and the last 5s interval expressed as a percentage.

The maximal dynamic isokinetic strength of the elbow flexors (EF) and knee extensors (KE) was determined utilizing the Cybex isokinetic dynamometer. Subjects were tested at angular velocities of 30° and 180° /s using techniques developed in this laboratory (15). Isometric handgrip strength was also measured with a handgrip dynamometer (15).

Two assessments of lifting capacity were made at each of the three testing periods. Maximal lift capacity to 152 cm was determined using the incremental dynamic lift (IDL) device where weights were raised on a vertical slide in incremental steps until a maximum lift was achieved (16). A second test of maximal lift capacity to a height of 132 cm was performed using a weighted box. From 2-10 kg of weight were added to the box with each successive lift attempt until a maximum was reached.

The physical task performance of each subject was evaluated twice during each day of the scenario by senior, noncommissioned officer personnel knowledgeable in all phases of artillery operations. Two evaluators who rotated on a 12-hour basis (0700 to 1900 hrs and 1900 to 0700 hrs) were assigned to each guncrew. A rating scale from 1 to 10 (with 10 being the highest score) (Appendix A) was used to rate the soldier's ability to perform all physically demanding tasks. The rating reflected such attributes as how

energetically or actively tasks were performed, the ability to handle the physical demands of the job, signs of fatigue versus "freshness", and the forcefulness or aggressiveness displayed in the performance of tasks.

The intensity of the physical activity of the scenario was estimated using portable, electrocardiographic (ECG) tape recorders (Medilog, Oxford Instruments) worn by the crewmen. A three lead, V_5 ECG configuration optimized the R-wave amplitude from which heart rate was determined. Cassette tapes were changed and the integrity of the recorder and ECG preparation evaluated each day between 0700-0800 hr. The daily heart rate for each subject was recorded on one, 24-hr cassette tape. This was replayed for computer analysis through an Oxford replay unit interfaced to a Hewlett-Packard 85A desk top computer (17).

A baseline heart rate was measured on all subjects each morning during the exchange of tares. This heart rate was taken with the subject standing and served as a basis for determining the time spent sleeping and at heart rates above 25%, 50%, and 75% of maximal heart rate. The criterion used to estimate sleep was a heart rate 10 beats/min below the baseline value which persisted for 20 min or more. Heart rates at 25%, 50%, and 75% of maximal heart rate were calculated by multiplying the difference between the maximal and baseline heart rates by 0.25, 0.50, and 0.75 and then adding these values to the baseline heart rate.

A one-way analysis of variance for repeated measures was used to determine significant differences in physical fitness capacities resulting from the 8-day scenario. Correlational analysis was used to relate physical fitness to physical task performance.

RESULTS

Baseline phase. The anthropometric variables and physiological capacities measured during the baseline data collection phase are summarized in Tables 1-3. The age range of the subjects was 18-30 yrs, the body weight range was 55 to 118 kg, and the percent body fat range was 5 to 27%. Only three soldiers had percent body fat values over 20%. The mean (\pm SD) maximal aerobic power ($\dot{V}O_2\text{max}$) for all subjects was 52.1 ± 5.5 ml/kg·min with a range from 41.2 to 68.0 ml/kg·min. The values for $\dot{V}O_2\text{max}$, anaerobic power, and muscular strength are comparable to other Army populations of similar age (4,15,18).

There were no statistically significant differences among the three gun crews for any of the physiological measurements made during the baseline period.

Field performance and exercise capacity. The results of the performance scores for the two rating periods are presented in Table 4. The physical performance of soldiers from Alpha battery was rated as significantly lower at night (1900 - 0700 hrs) compared to the day (0700 - 1900 hrs) whereas the opposite was true for soldiers from the other two guncrews. The combined results show a significantly greater performance rating between 1900-0700 hrs than from 0700-1900 hrs. The mean ratings during the night time period were significantly higher for Bravo battery compared to either Alpha or Charlie but no differences occurred among batteries during the day.

Because of the significant difference in performance scores between the two rating periods, the data were not combined and separate analyses were used to relate physical fitness capacity to physical task performance. Table 5 shows the relationships between the performance scores and anthropometric and fitness variables for both rating periods. In general, the correlations were

**Table 1. Physical characteristics of subjects-
baseline data (mean \pm SD)**

	Battery			
	<u>Alpha</u>	<u>Bravo</u>	<u>Charlie</u>	<u>Total</u>
n	8	8	8	24
Age, yrs	21.9 \pm 3.0	21.9 \pm 4.3	22.8 \pm 3.8	22.2 \pm 3.6
Height, cm	179.1 \pm 5.8	175.3 \pm 4.5	175.0 \pm 6.2	176.5 \pm 5.5
Weight, kg	81.2 \pm 15.7	74.0 \pm 7.3	73.0 \pm 10.3	76.1 \pm 11.1
Body Fat, %	14.8 \pm 6.6	11.1 \pm 3.0	11.1 \pm 2.0	12.3 \pm 3.9
Fat free mass, kg	68.5 \pm 9.8	59.0 \pm 18.0	55.1 \pm 20.9	60.9 \pm 16.2
$\dot{V}O_2$ max, ml/kg·min	51.4 \pm 5.0	54.8 \pm 7.1	50.1 \pm 4.5	52.1 \pm 5.5
Heart rate max, bpm	192 \pm 7	193 \pm 8	189 \pm 6	191 \pm 7

Table 2. Muscular strength and lifting capacity-
baseline data (mean \pm SD)

	Battery			
	<u>Alpha</u>	<u>Bravo</u>	<u>Charlie</u>	<u>Total</u>
EF, 30°/s,Nm	56.6 \pm 11.4	59.3 \pm 11.1	52.3 \pm 10.2	56.1 \pm 10.9
EF, 180°/s,Nm	44.5 \pm 12.5	46.5 \pm 9.6	39.9 \pm 9.0	43.6 \pm 10.4
KE, 30°/s,Nm	239 \pm 60	226 \pm 64	231 \pm 59	232 \pm 61
KE, 180°/s,Nm	168 \pm 39	155 \pm 32	151 \pm 37	158 \pm 36
HG,kg	63.0 \pm 10.8	64.1 \pm 8.9	59.2 \pm 10.8	62.1 \pm 10.2
IDL,kg	80.7 \pm 19.9	77.1 \pm 10.1	75.1 \pm 11.5	77.6 \pm 13.8
Box Lift, kg	64.8 \pm 14.9	58.0 \pm 9.8	59.4 \pm 11.2	60.7 \pm 12.0

Abbreviations: EF = elbow flexion, KE = knee extension, HG = handgrip,
IDL = incremental dynamic lift.

Table 3. Upper and lower body anaerobic power-baseline data (Mean \pm SD).

	Battery			
	<u>Alpha</u>	<u>Bravo</u>	<u>Charlie</u>	<u>Total</u>
<u>Upper Body</u>				
PP, W	623 \pm 101	556 \pm 87	547 \pm 87	575 \pm 97
PP, W/kg	7.7 \pm 0.7	7.5 \pm 0.9	7.6 \pm 0.5	7.6 \pm 0.7
MP, W	469 \pm 83	416 \pm 62	389 \pm 89	425 \pm 78
MP, W/kg	5.8 \pm 0.8	5.6 \pm 0.7	5.4 \pm 0.6	5.6 \pm 0.7
PD, %	46.6 \pm 10.8	46.8 \pm 9.1	50.0 \pm 8.7	48.5 \pm 9.7
<u>Lower Body</u>				
PP, W	666 \pm 123	669 \pm 82	551 \pm 151	629 \pm 121
PP, W/kg	8.3 \pm 1.3	8.9 \pm 1.0	7.6 \pm 1.2	8.3 \pm 1.2
MP, W	484 \pm 94	485 \pm 67	397 \pm 93	445 \pm 85
MP, W/kg	6.0 \pm 0.9	6.5 \pm 0.8	5.5 \pm 0.7	6.0 \pm 0.8
PD, %	55.0 \pm 8.5	48.5 \pm 6.5	44.7 \pm 16.2	49.4 \pm 10.4

Abbreviations: PP = peak power, MP = mean power, PD = power decrease

Table 4. Field performance scores by rating period (mean \pm SD).

<u>Period (hrs)</u>	<u>Battery</u>			<u>Mean</u>
	<u>Alpha</u>	<u>Bravo</u>	<u>Charlie</u>	
0700 -	6.6	6.0	4.9	5.9
1900	± 0.5	± 1.0	± 1.8	± 1.3
1900 -	5.6*	8.0*	6.6*	6.7*
0700	± 0.6	± 0.2	± 1.0	± 1.2

* $p < .05$, Between periods

Table 5. Correlation coefficients between field performance scores and physical fitness capacities.

	Period	
	<u>0700 - 1900</u>	<u>1900 - 0700</u>
Age, yrs.	0.128	0.130
Body weight, kg	0.277	-0.161
Body Fat, %	0.218	-0.25
Fat Free Mass, kg	-0.070	-0.343
VO ₂ max, ml/kg-min	-0.005	0.239
EF (30°/s), Nm	0.021	0.071
EF (180°/s), Nm	-0.001	0.015
KE (30°/s), Nm	0.074	-0.015
KE (180°/s), Nm	0.195	-0.071
Handgrip, kg	0.174	0.218
IDL, kg	0.036	-0.255
Box Lift, kg	0.071	-0.133
Upper Body Wingate Test		
Peak Power, W	0.081	-0.364
Mean Power, W	0.314	-0.222
Power Decr, %	-0.325	-0.453*
Lower Body Wingate Test		
Peak Power, W	0.173	-0.107
Mean Power, W	0.297	-0.003
Power Decr, %	-0.015	-0.558*

* $p < .05$

quite low. Percent power decrease from the upper body ($r = -0.453$) and lower body ($r = -0.558$) Wingate test was the only variable significantly correlated with performance but only during the night period.

The mean combined physical performance scores each day of the scenario are presented in Table 6. The scores were significantly higher on the first and last days of the scenario compared to the other days. No differences in performance were seen from days 2 through 7.

Pre-post scenario changes. Tables 7-10 present the changes in body composition, anaerobic power, muscular strength, and lifting capacity, respectively, that occurred from pre to post-scenario. The mean data are presented for all subjects combined and for each of the three gun crews individually.

A significant decrease in percent body fat and a corresponding increase in fat free mass were seen for all subjects (Table 7). These changes were primarily due to the much greater decrease in percent body fat of soldiers from Charlie battery than those from the other two guncrews. No change in body weight for the entire group or any of the individual gun crews occurred over the 8-days.

In general, only small changes were seen in power outputs measured during upper body anaerobic exercise from pre to post-scenario (Table 8). However, the 4% increase in mean power seen for all subjects did reach the level of statistical significance ($p < .05$). This was due to a 6-7% increase in the soldiers from Bravo and Charlie batteries as those of Alpha showed no change.

All of the measures of muscular strength were significantly increased from pre to post-scenario (Table 9). The isokinetic measures of strength increased from 12 to 18% while isometric handgrip strength increased 7% for all

Table 6. Physical performance scores during each day of the scenario (mean \pm SD, n = number of subjects).

	<u>Day</u>								
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>Mean</u>
Score	6.8*	6.3	6.2	6.4	6.3	6.0	5.7	6.8*	6.3
	± 1.6	± 1.6	± 1.4	± 1.4	± 1.1	± 0.8	± 1.0	± 0.8	± 1.2
n	23	23	22	22	22	20	20	22	

* $p < .05$, compared to other days.

Table 7. Changes in body composition from pre to post scenario (mean \pm SD).

	<u>Pre</u>	<u>Post</u>	<u>% Diff.</u>
Body weight, kg			
Alpha	80.6 \pm 18.1	81.0 \pm 18.0	0.5
Bravo	73.9 \pm 7.7	74.0 \pm 7.4	0.1
Charlie	71.7 \pm 10.8	72.3 \pm 11.0	0.8
All subjects	75.6 \pm 12.7	75.9 \pm 12.7	0.4
Body Fat, %			
Alpha	17.1 \pm 4.6	16.7 \pm 5.0	-2.3
Bravo	15.7 \pm 2.8	15.4 \pm 2.4	-1.9
Charlie	16.3 \pm 4.2	14.5 \pm 3.5*	-11.0
All subjects	16.3 \pm 3.7	15.6 \pm 3.6*	-4.3
Fat Free Mass, kg			
Alpha	66.4 \pm 12.4	66.9 \pm 11.7	0.8
Bravo	62.3 \pm 6.5	62.6 \pm 6.0	0.5
Charlie	59.8 \pm 7.8	61.7 \pm 8.7*	3.2
All subjects	63.0 \pm 9.1	63.8 \pm 8.8*	1.3

* $p < .05$

Table 8. Changes in upper body anaerobic power from pre to post scenario (mean \pm SD).

	<u>Pre</u>	<u>Post</u>	<u>% Diff.</u>
Peak Power, W			
Alpha	630 \pm 120	616 \pm 99	-2.2
Bravo	596 \pm 55	621 \pm 79	4.2
Charlie	573 \pm 114	594 \pm 117	3.7
All subjects	601 \pm 94	613 \pm 92	2.0
Mean Power, W			
Alpha	493 \pm 98	490 \pm 106	-0.6
Bravo	451 \pm 69	479 \pm 60	6.2
Charlie	442 \pm 89	473 \pm 82*	7.0
All subjects	462 \pm 83	481 \pm 80*	4.1
Power Decr, %			
Alpha	44.9 \pm 9.1	42.7 \pm 5.2	-4.9
Bravo	47.2 \pm 9.5	45.4 \pm 8.9	-3.8
Charlie	42.1 \pm 12.7	39.7 \pm 9.3	-5.7
All subjects	45.1 \pm 10.0	43.1 \pm 8.0	-4.4

* p < .05

Table 9. Changes in muscular strength from pre to post scenario (mean \pm SD).

	<u>Pre</u>	<u>Post</u>	<u>% Diff.</u>
EF (30°/s), Nm			
Alpha	55.0 \pm 9.5	62.5 \pm 13.6*	13.6
Bravo	58.9 \pm 11.0	62.9 \pm 13.2*	6.8
Charlie	49.9 \pm 7.6	60.0 \pm 10.1*	22.2
All subjects	55.3 \pm 10.0	62.1 \pm 12.2*	12.3
EF (180°/s), Nm			
Alpha	43.8 \pm 7.8	47.9 \pm 12.3	9.4
Bravo	43.0 \pm 9.5	50.3 \pm 13.4*	17.0
Charlie	35.8 \pm 5.7	47.2 \pm 9.0*	31.8
All subjects	41.5 \pm 8.5	48.7 \pm 11.7*	17.3
KE (30°/s), Nm			
Alpha	233 \pm 51	248 \pm 60*	6.4
Bravo	216 \pm 66	261 \pm 65*	20.8
Charlie	173 \pm 37	227 \pm 28*	31.2
All subjects	212 \pm 58	249 \pm 57*	17.5
KE (180°/s), Nm			
Alpha	160 \pm 39	174 \pm 40*	8.8
Bravo	150 \pm 31	173 \pm 36*	15.3
Charlie	122 \pm 27	143 \pm 28*	17.2
All subjects	147 \pm 35	167 \pm 37*	13.6
Handgrip, kg			
Alpha	64.6 \pm 9.0	69.4 \pm 9.5*	7.4
Bravo	62.9 \pm 5.3	68.9 \pm 11.2	9.5
Charlie	59.7 \pm 9.9	60.4 \pm 9.5	1.2
All subjects	62.7 \pm 7.8	66.9 \pm 10.5*	6.7

* $p < .05$

Table 10. Changes in lifting capacity from pre to post scenario (mean \pm SD).

	<u>Pre</u>	<u>Post</u>	<u>% Diff.</u>
IDL, kg			
Alpha	78.3 \pm 20.4	93.4 \pm 19.3*	19.3
Bravo	74.6 \pm 10.6	83.2 \pm 11.8*	11.4
Charlie	65.0 \pm 11.7	71.8 \pm 9.7	10.5
All subjects	73.4 \pm 15.3	83.7 \pm 16.2*	14.0
Box Lift, kg			
Alpha	67.2 \pm 14.9	76.2 \pm 18.1	13.4
Bravo	57.2 \pm 7.2	66.2 \pm 11.8*	15.7
Charlie	60.1 \pm 10.3	66.8 \pm 14.6	11.1
All subjects	61.4 \pm 11.6	69.8 \pm 15.0*	13.7

* $p < .05$

subjects. Each guncrew showed increases in all of the strength measures but, with the exception of handgrip strength, soldiers from Charlie battery showed the greatest increases followed by those from Bravo and Alpha.

Significant increases in maximal lifting capacity also occurred from pre to post-scenario (Table 10). Both the IDL and box lift increased approximately 14% for all subjects combined with each battery showing at least a 10% increase.

Field Heart Rate Monitoring

The mean time spent per day sleeping and at various levels of physical activity as determined from continuous heart rate monitoring is presented in Table 11. Incomplete heart rate data were obtained for many subjects over the 8-day period due either to a failure of the electrode preparation to remain intact or to the subject removing the electrodes because of skin irritation or interference with movement. Thus, the number of subjects with complete data varied considerably across days as seen in the table. The mean amount of sleep obtained daily for all subjects was 5.3 hrs with individual averages ranging from 3.5 to 6.8 hrs. Approximately 90% of this sleep came during the nocturnal period. No significant differences occurred across days in the time spent asleep for any of the guncrews. In addition to sleep, subjects spent a mean of 5.5 hrs per day at heart rates equal to or below the baseline level. The baseline heart rates were not significantly different among guncrews and averaged (\pm SD), 77 ± 2 , 76 ± 3 , and 81 ± 3 for Alpha, Bravo, and Charlie, respectively.

Table 11 also depicts the mean time that subjects spent each day at physical intensities equal to or above 25%, 50%, and 75% of their maximal

Table 11: Time spent sleeping and at various heart rate (HR) intensities during each day of the scenario (mean \pm SD, n = number of subjects).

	Day								
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>Mean</u>
Sleep, hr	5.6 ± 1.4	5.5 ± 1.6	4.7 ± 1.0	5.3 ± 1.0	5.3 ± 1.0	4.8 ± 1.5	5.5 ± 1.2	5.3 ± 1.2	5.3 ± 1.3
Baseline HR, hr	5.2 ± 2.3	6.5 ± 2.6	6.4 ± 3.1	6.7 ± 2.8	5.2 ± 2.0	5.2 ± 2.5	3.4 ± 2.5	5.6 ± 2.9	5.5 ± 2.8
HR 25%, hr	1.70 ± 1.66	2.04 ± 1.28	2.49 ± 2.10	2.49 ± 1.54	2.85 ± 1.83	3.19 ± 2.15	3.29 ± 2.27	2.15 ± 1.45	2.53 ± 2.16
HR 50%, min	14.9 ± 15.1	14.6 ± 15.7	18.6 ± 17.1	26.4 ± 18.7	28.8 ± 30.4	29.2 ± 24.0	23.6 ± 21.3	19.5 ± 23.0	22.0 ± 20.7
HR 75%, min	1.4 ± 2.5	0.9 ± 2.2	2.3 ± 4.3	3.6 ± 4.4	3.5 ± 5.0	6.1 ± 8.1	2.1 ± 3.6	3.6 ± 6.8	2.9 ± 4.6
n	12	15	20	18	13	13	13	11	

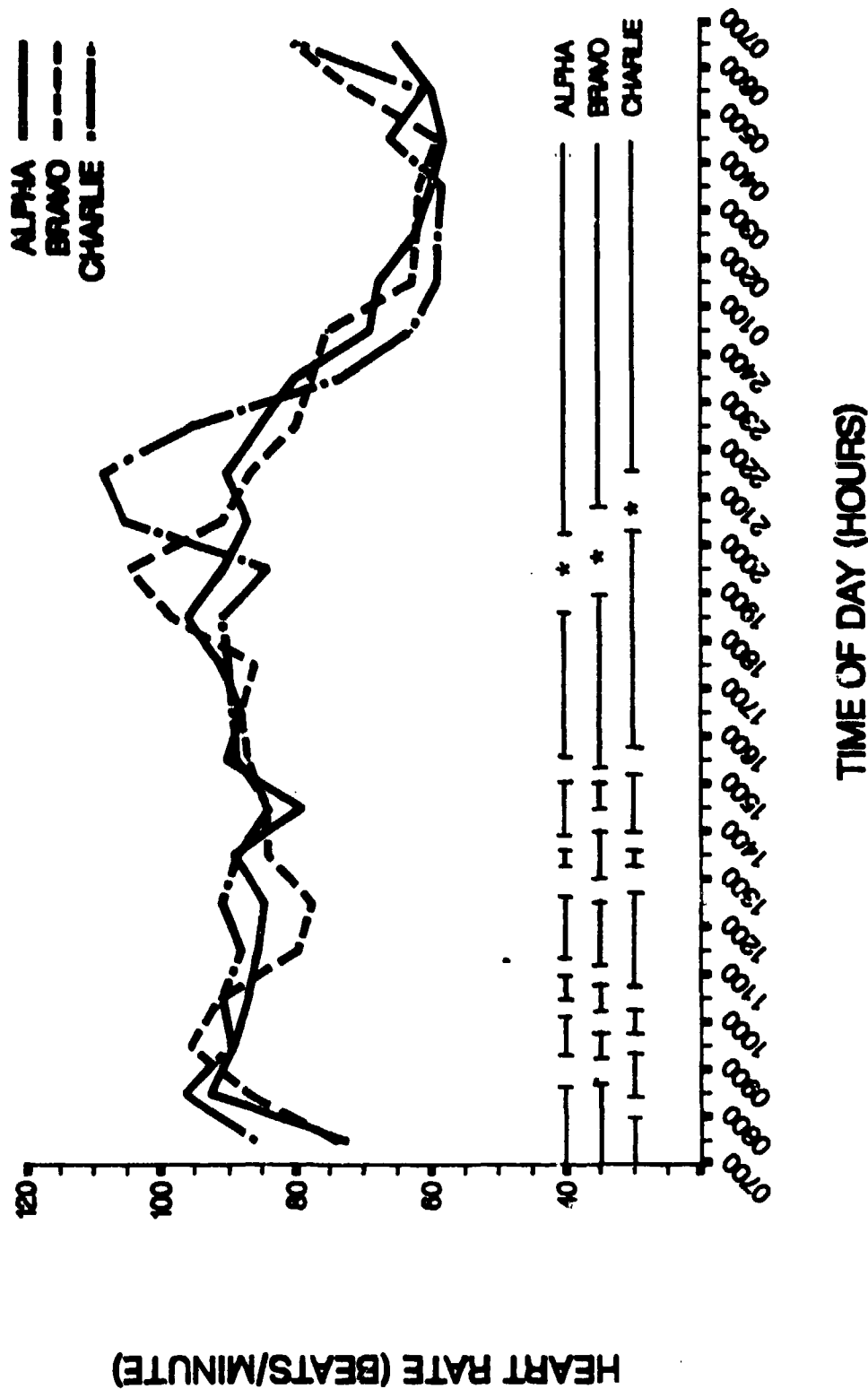
exercise heart rates. The mean \pm SD heart rates at these three levels were 106 \pm 5, 134 \pm 5 and 163 \pm 6 beats per minute, respectively. As can be seen, the time spent at heart rates 25%, 50%, and 75% of maximal averaged 2.5 hr, 22 min and 2.9 min per day, respectively. At all heart rate intensities, values for Alpha and Bravo were significantly lower than for Charlie ($p < .05$).

The mean hourly heart rates for each guncrew during Day 4 of the scenario are shown in Figure 1. This day was selected because of the high number of gun movements (7) and fire missions (60). Similar heart rate patterns were found for the other days where mean values generally ranged from 80 to 100 beats per minute during the active period. A general pattern was established which was similar for each day of the scenario. Gun movements occurred from approximately 0800 to 1600 with ammunition resupply taking place in the late evening. The highest mean heart rates were found for each guncrew during this latter period. A relative lull in operations occurred between 2300 and 0700 hrs where fewer fire missions took place than during daylight hours and there were no gun movements.

DISCUSSION

The major finding in this study was the lack of any evidence of physical fatigue as assessed by measures of physical fitness capacity and ratings of physical performance resulting from participation in an 8-day continuous field artillery operation. The observations relative to changes in muscle strength and endurance contrast with those reported by Murphy et al. (4) who found reductions in upper body mean power from the Wingate test and in isokinetic strength of the elbow flexors for infantry soldiers immediately after a 5-day combat-simulated scenario. More recently, Legg and Patton (6) also reported

FIGURE 1. Mean hourly heart rates for each guncrew during Day 4 of the scenario. Depicted at bottom are periods of occupation of (—) and displacement from (---) gun positions. The period of ammunition resupply is designated as (*).



decrements in upper body mean power as well as isometric handgrip strength following an 8-day field artillery trial. In both of these studies there was an unusually high degree of upper body exercise throughout the scenario in the form of either backpack load carriage (4) or manual handling of artillery shells (6).

The absence of any decrease in measures of physical capacity and ratings of physical task performance may reflect differences either in the amount of dedicated sleep the soldiers obtained and/or in the intensity of the physical task demands compared to the other scenarios. Both factors would significantly impact upon the physical performance of soldiers in a continuous operations environment. In the study by Legg and Patton (6) soldiers handled a significantly greater number of artillery shells per day, lost a mean of 1.9% in body weight over an 8-day period, and averaged less sleep (approximately 3 hr) per day compared to the 5.3 hrs of sleep for subjects in the present study. These differences suggest a much greater energy expenditure and thus a more physically demanding scenario which could account for the differences in muscular strength and anaerobic power seen during post-testing between these two studies. Furthermore, in the 5-day infantry (17) scenario soldiers spent nearly 70% more time per day at heart rates equal to or greater than 50% of their maximal heart rates further suggesting this scenario was more physically demanding than the present one.

The scenario evaluated herein was considered to be realistic in terms of the sleep obtained and the frequency and intensity of the physical tasks performed. In accordance with current doctrine guncrews were allowed to sleep when possible. The crewchiefs were given latitude in rotating individual crewmembers on the guns so that dedicated sleep could be obtained. To further

facilitate sleep the intensity of the operation was reduced during the early morning hours. Thus, sleep deprivation was not a significant contributor to the overall stress of this particular scenario. In addition, the relatively little time spent at heart rates exceeding 50% of maximal suggests that this scenario could be classified, at best, as "moderate" in terms of its physical activity intensity. However, this would appear to be in agreement with the observations made by Waldun and Huser (19) as cited in Rognum et al. (20) that soldiers during simulated combat situations exceed 50% of their maximal oxygen uptake for only short periods of time.

The significant increases in measures of muscular strength and lifting capacity found during post-testing suggest either a training effect or a difference in the motivation of soldiers than was displayed during the pre-testing period. It is known that strength can improve at a rate between 0.3-5.0% per session using a progressive resistance model depending on the initial training state and type of contraction employed (21). However, initial gains in strength may be due to a "learning effect" as a result of neuromuscular adaptation (22). In addition, during the post-testing period, there was a general sense of euphoria among the soldiers as a result of successfully completing the trial which was preceded by significantly higher performance scores on the final day of the scenario. Thus, a greater level of motivation may have accounted for some of the changes seen in muscular strength post-scenario.

Another principle finding of this study was the lack of any significant relationship between physical fitness capacities and performance of physical tasks during the scenario. This may have been due to a number of reasons. One of the most plausible was the inability of the raters to adequately

discriminate among soldiers in assessing their physical performance. This is suggested by the very similar and frequently identical ratings given to a number of soldiers during the same rating period. Although the rating scale ranged from 1 to 10, the individual mean scores only ranged from 4.3 to 7.5. There also were differences in the way performance was rated as evidenced by significant differences among the three batteries and between rating periods which could have impacted on the correlational analysis. Furthermore, the lack of any significant relationship could be due, in part, to the soldiers being a fairly homogeneous group in terms of their exercise capacities. However, a fairly wide range in values was found for most fitness variables. Finally, the relatively small number of subjects who were tested and evaluated during the scenario made it difficult to establish statistically significant relationships between fitness and performance. A significant inverse relationship, however, was found between the performance score and power decrease measured from the Wingate test. Since the latter is purported to be a measure of fatigue, a case could be made that soldiers who showed less fatigue performed better on the physical tasks during the scenario. However, since this relationship was found only during the 1900-0700 rating period, considerable doubt is raised as to its significance.

The continuous measurement of heart rate provided a suitable means to assess the physical intensity of continuous military operations as previously shown (17). However, it must be kept in mind when evaluating such data that heart rate measurement is an indirect estimation of energy expenditure and subject to a large prediction error. Factors such as state of physical training, type of physical activity, emotion, fatigue, etc. can markedly alter the relationship between heart rate and oxygen uptake (23). Therefore, no

attempt was made in this study to estimate energy expenditure from the heart rate recordings. The data do show, however, that high levels of physical activity were attained only infrequently and intermittently and that during the active periods, heart rates averaged below 100 beats/min.

CONCLUSIONS

1. No significant relationships were found between physical fitness capacity, as measured by laboratory tests, and ratings of physical task performance during the 8 days of continuous operations. These results, however, should not minimize the importance of physical fitness in the performance of tasks involving strenuous work as an abundance of evidence exists showing high levels of fitness to be essential for the efficient performance of physical tasks. The probable reasons for the negative findings have been discussed.

2. Soldiers who are allowed 5 hrs of sleep per day and are required to perform at relatively moderate levels of physical intensity, with only brief periods at high intensity, show no decrements in physical fitness capacity or evidence of physical fatigue for up to 8 days of continuous operations.

3. The levels of aerobic power, anaerobic capacity and muscular strength of the artillerymen in this study were comparable to other Army populations of similar age and proved adequate to meet the physical demands of this particular combat simulated scenario.

4. Soldiers undergoing realistic, continuous field artillery operations are able to obtain adequate sleep and spend only short periods of time each day at high levels of physical activity.

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APPENDIX A
INDIVIDUAL PHYSICAL PERFORMANCE DATA
RATING FORM

FT SILL: ARTILLERY RESEARCH STUDY
INDIVIDUAL PHYSICAL PERFORMANCE DATA

DATA COLLECTOR: _____

UNIT ID: _____

DATE (DDMMYY): _____

CYCLE: _____

GUN /FDC: _____

INSTRUCTIONS

Select the single most appropriate rating (by placing an "X" in the corresponding column) which best describes the over-all physical performance of each soldier while carrying out his duties/tasks during the 12 hour period of your observation.

It should reflect such attributes as: how energetic or active he performs his tasks, his ability to handle the physical demands of his job, physical ability to "keep-up", signs of fatigue versus "freshness", forcefulness or aggressiveness in performing his physical duties.

[illegible]

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